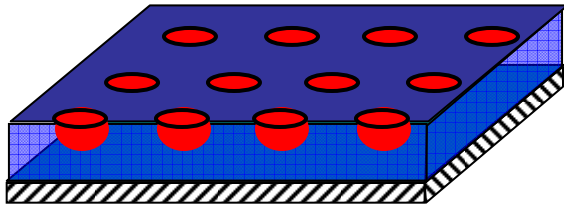
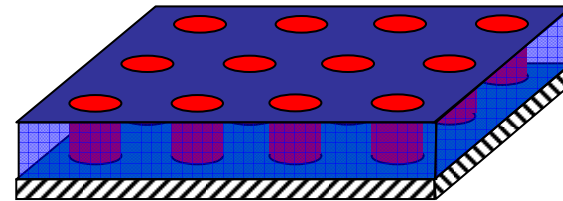


Block Copolymer Lithography

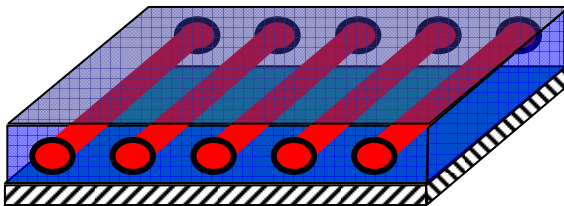
Spheres



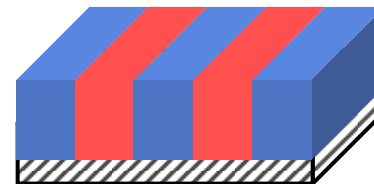
⊥ Cylinders



|| Cylinders



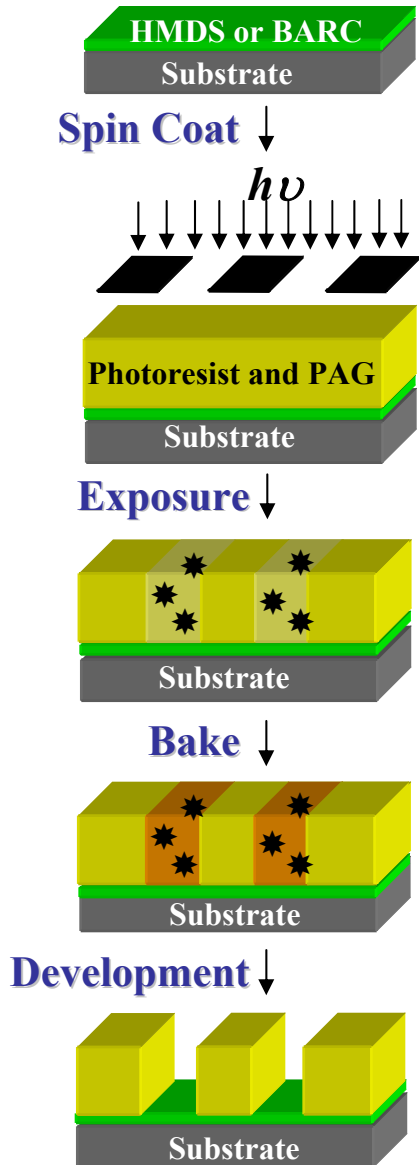
Lamellae



- No Wetting Problems
- Templates

- Pattern Transfer Advantages
- Connectivity
- High Aspect Ratio

Photolithography



Essential Attributes of Photolithography:

- Patterning perfection
- Registration and overlay
- Non-regular shaped features

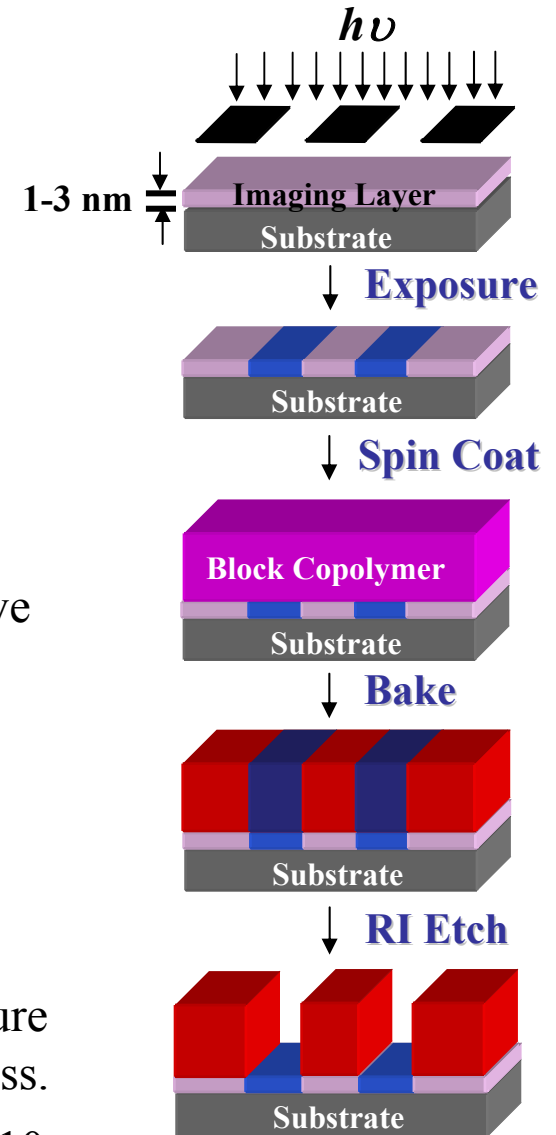
Technology Gap:

- Significant resources have been allocated to exposure tools
- Relatively modest investments have been made in sub-30 nm rsists

Key Concepts of Block Copolymer Lithography:

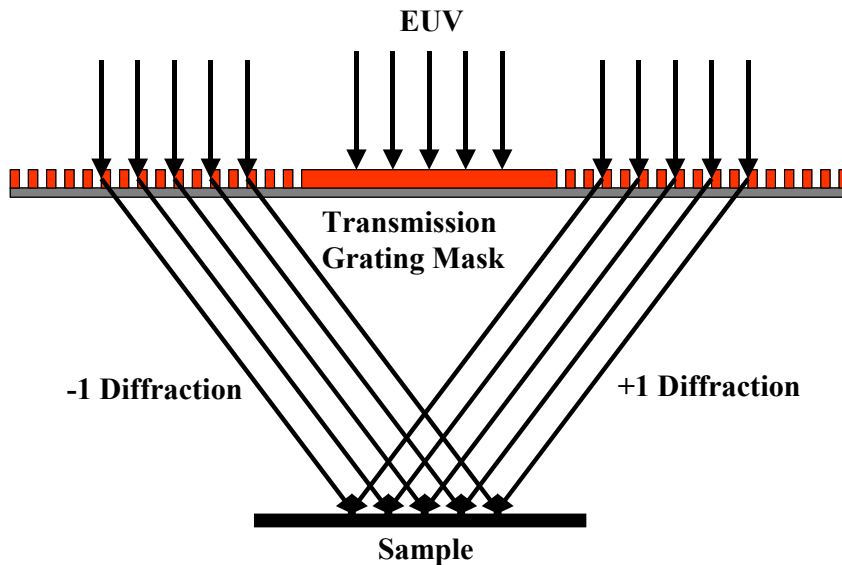
- Can be integrated into existing manufacturing processes.
- Thermodynamics determines feature dimensions and line edge roughness.
- Scalable to feature dimensions of 10 nm and below

Directed assembly of block copolymers



EUV-IL Using Transmission Membrane Masks: (A UW-NSEC Shared Facility at the UW Synchrotron Radiation Center)

**Two, three, or four diffracted beams
interfere to yield dense lines and spaces, or
cubic or hexagonal arrays of dots**



Pattern period is half of grating period

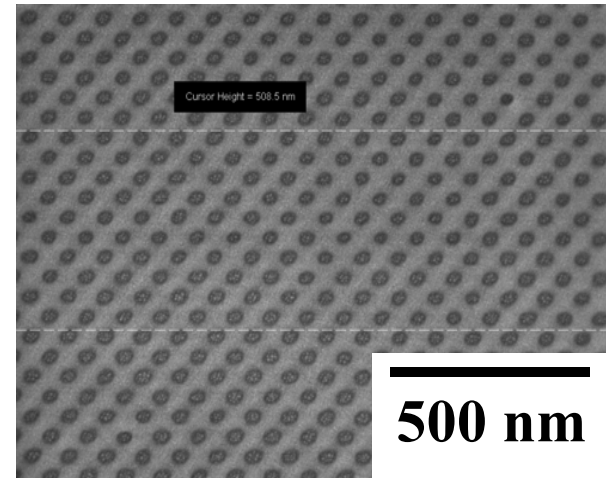
Collaboration with Harun Solak-Swiss Light Source

H. H. Solak, C. David, J. Gobrecht,

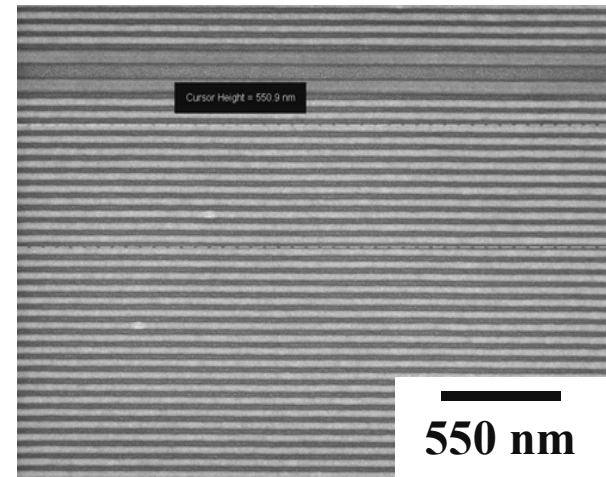
V. Golovkina, F. Cerrina, S. O. Kim and P. F. Nealey

Sub-50nm period patterns with EUV interference lithography,
Microelectronic Engineering 67-68 56-62 (2003).

PMMA



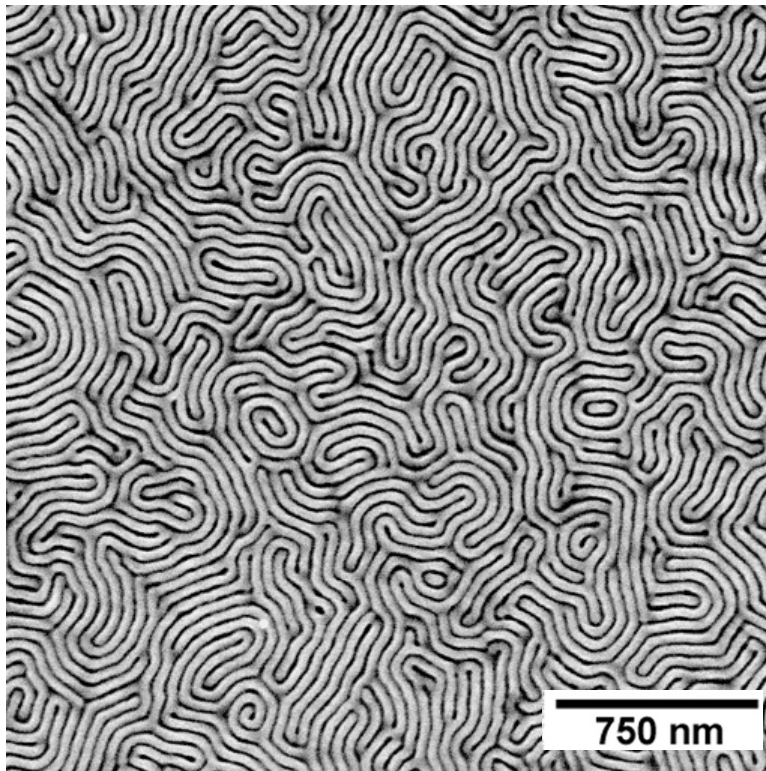
Cubic Array of Holes, 57 nm pitch



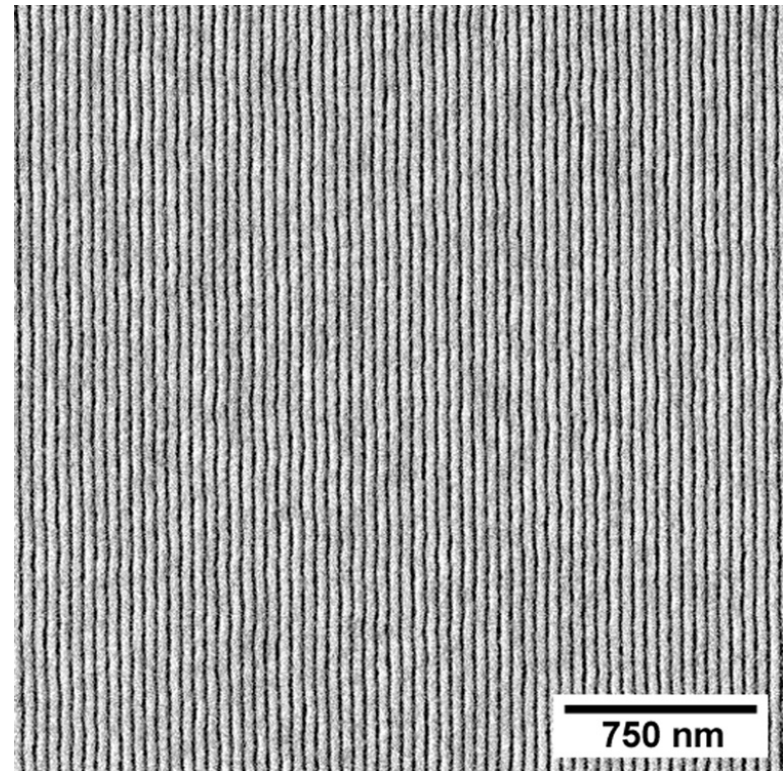
1:1 Lines, 55 nm Pitch

Perfect Registered Assembly of Block Copolymer Domains Over Arbitrarily Large Areas

Unpatterned Surface



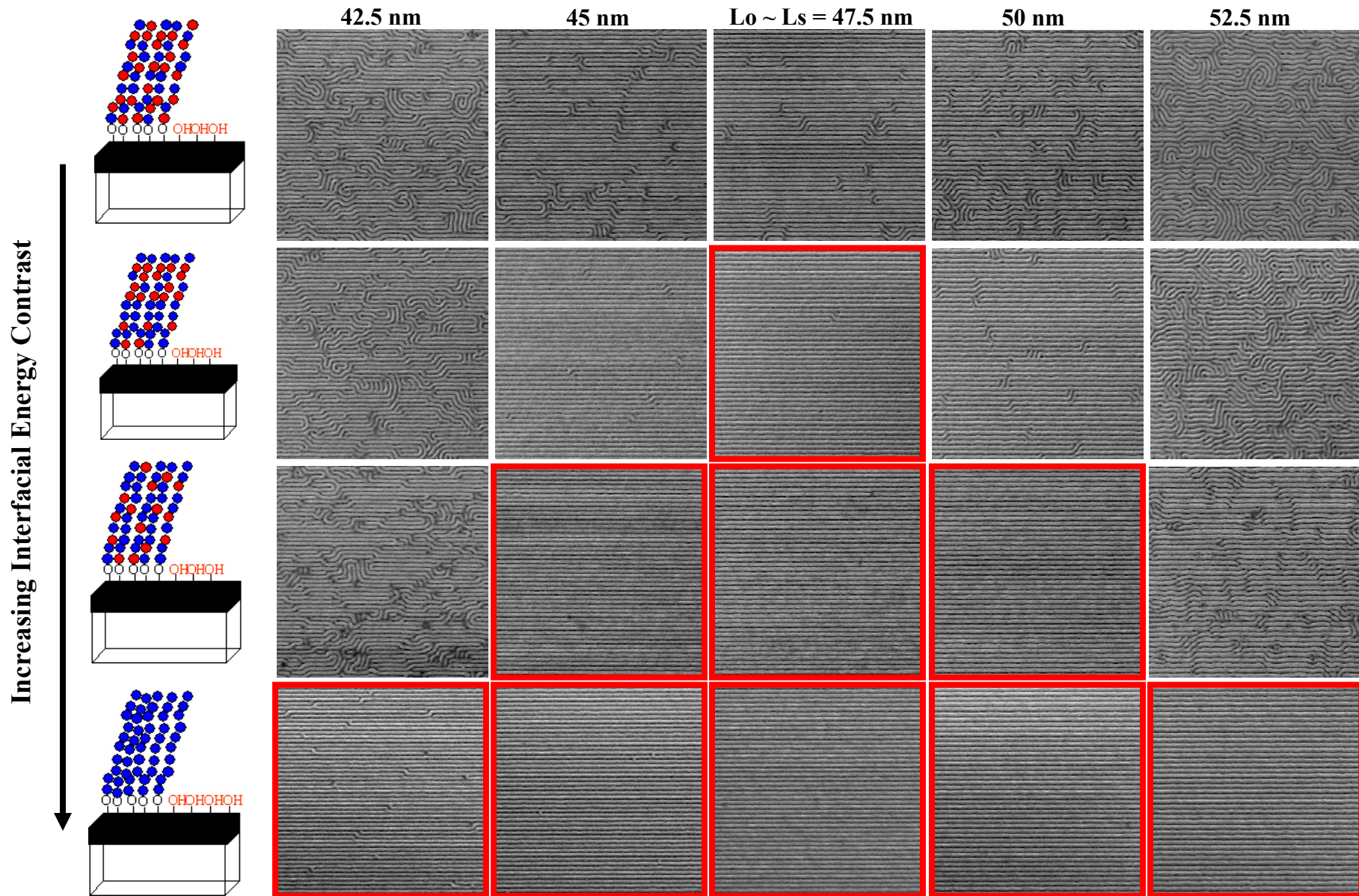
Patterned Surface $L_s = L_0$



Symmetric Poly(styrene-*b*-methacrylate) $L_0 \sim 48$ nm

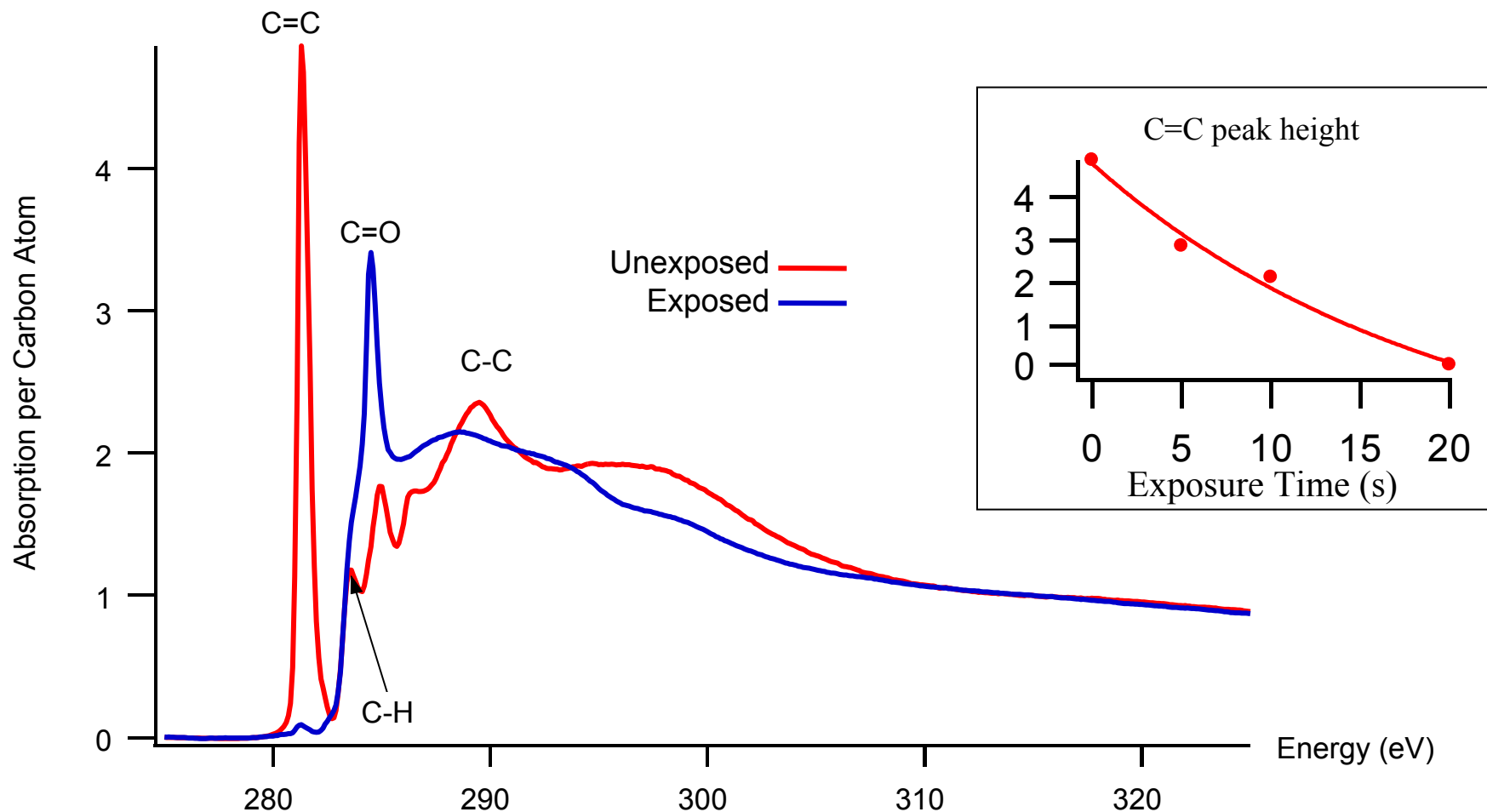
S. O. Kim, H. H. Solak, M. P. Stoykovich, N. J. Ferrier, J. J. de Pablo, P. F. Nealey,
Nature, **2003**, 424, 411.

Precise control over molecular dimensions of block-copolymer domains using the interfacial energy of chemically nanopatterned substrates, Adv. Mat., 2004, 16, 1315



Characterization of chemical surface patterns using NEXAFS

(Kelly Mallon, Franz Himpsel, UW Physics)

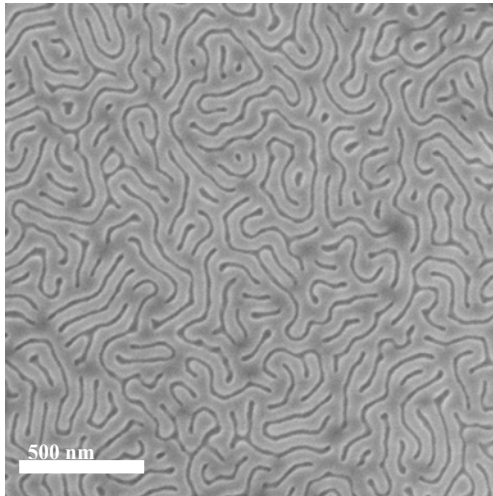


- Characterization of polystyrene brushes exposed to an oxygen plasma
- C=C bonds cleaved, oxygen incorporated as C=O
- Carbon reduced to 25% (from absolute intensity)

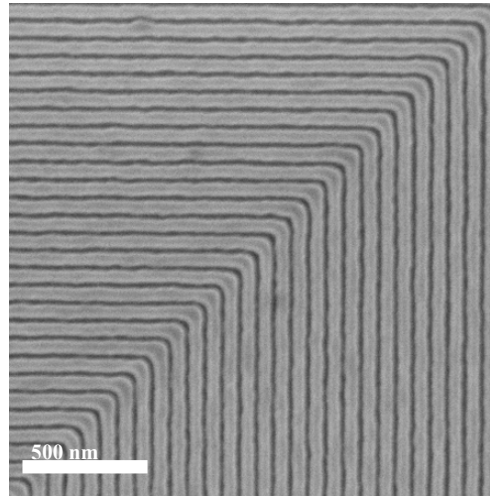
Directed assembly of block copolymer blends into non-regular device oriented structures

Mark P. Stoykovich, Marcus Müller, Sang Ouk Kim, Harun H. Solak, Erik W. Edwards, Juan J. de Pablo, Paul F. Nealey, *Science*, 2005, 308, 1442-1446.

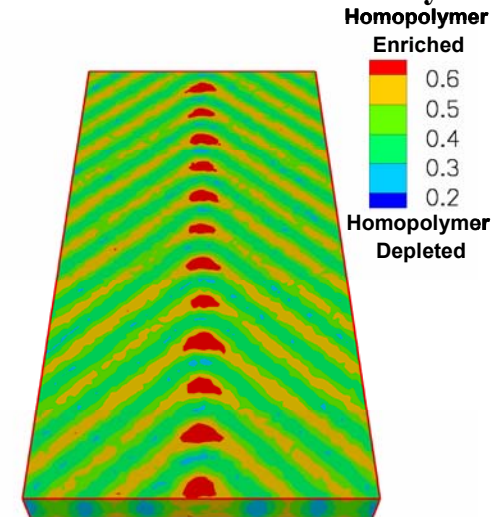
Homogeneous Surface



Directed assembly on chemically patterned surface



Redistribution of homopolymer facilitates assembly



Ternary blend:

PS-*b*-PMMA / PS / PMMA



$$\phi_H = 0.4, N_{BC} = 1040, \alpha = 0.4$$

Block copolymer materials that naturally form simple periodic structures were directed to assemble into non-regular device oriented patterns on chemically nanopatterned substrates. **The ability to pattern non-regular structures using self-assembling materials creates new opportunities for nanoscale manufacturing.**